Book Reviews

Biological Effects of Electric and Magnetic Fields. Vol. 1: Sources and Mechanisms. Vol. 2. Beneficial and Harmful Effects by D. O. Carpenter and S. Ayrapetyan, Editors

Academic Press, New York, 1994. 369 and 357 pages. $99.00 each.

Reviewed by Kenneth R. Foster, Department of Bioengineering, University of Pennsylvania

[1]These two volumes address a vast and untidy subject that spills over into biophysics, medicine, engineering—and more recently, epidemiology, risk assessment, tort law, and public policy. One editor, David Carpenter, is a highly regarded and prolific neurophysiologist. Now Dean of the School of Public Health at the State University of New York at Albany, in the 1980s he administered a large research program (the New York Power Lines Project) on possible health effects of powerline fields. His coeditor is a biophysicist at the Armenian Academy of Sciences. Most of the nearly 50 coauthors are well known investigators in this field.

Most of the 29 mini-reviews that constitute this book are biologically oriented. They discuss reported effects of electromagnetic fields on gene transcription, the immune system, behavioral and neural effects, membrane effects, in vitro studies related to carcinogenesis, and so on. The last six chapters deal with cancer and other human health effects, and include discussions on exposure assessment, epidemiology, risk communication, and long-term animal studies. None of the chapters is definitive, and many have obvious gaps in coverage. Nevertheless, the authors touch on most of the major topics of interest to investigators in bioelectromagnetics.

There is much to praise in this book. Particularly well done are chapters on environmental electromagnetic fields (Deno and Carpenter), exposure assessment (Koifman and Thériault), and epidemiology (Savitz and Ahlbom). Other interesting discussions consider the thermal noise limits for producing effects in biological systems (by Weaver and Astumian) and electroporation and other high-field effects on membranes (by Zhelev and Needham). The volumes are nicely bound and well edited.

Some claims are astonishing and, if true, will give theorists a lot to think about. Ayrapetyan et al. report that the conductivity of calcium chloride solutions is changed after brief exposure to magnetic fields of a few hundred Gauss. They also report that the uptake of ^{45}Ca by snail ganglia is changed if solutions are first exposed to magnetic fields before being used to perfuse the cells.

More generally, the book, taken as a whole, is neither sufficiently quantitative nor sufficiently critical. To simply list reported effects, without carefully putting the studies into a context of other knowledge or assessing their validity, can be very misleading. Kholodov cites many reported neurobiological effects of electromagnetic fields (mostly from the Russian literature)—without once stating the exposure level and frequency!

The literature on biological and health effects of electromagnetic fields is a heterogeneous mixture of good science (notably, from a health perspective, a series of increasingly focused epidemiology and animal studies)—and scientific junk. The literature is awash with speculations about possible mechanisms of interaction, many too loose to be tested or inconsistent with well established physical principles (Adair, 1991). Many reported "effects" cannot be confirmed independently and may be artifacts (Carstensen, 1987; Foster, 1992). Many reported effects are close to the limits of statistical significance, were reported on the basis of a single experiment (often, it seems, not even repeated in the investigators' own laboratory), or the studies had gross technical flaws. A more penetrating and critical analysis is needed to help the reader separate the signal from the very large amount of scientific noise in this field.

A brief comment by Serduke et al. (Vol. 2, p. 153) illustrates the problem. It is "well known," the authors report, "that [electromagnetic field] exposure causes changes in the blood-brain barrier." Really? This has been a vexing issue for many years. The first claim that I can locate appeared in a Soviet journal in 1972. The issue came to life in 1975 when an American investigator reported that exposure to low level microwave energy caused the leakage of fluorescent dye from blood into the brain of rats. In the following decade, at least 15 groups worked on the problem, using progressively better controlled and more sensitive techniques. The effect went away except at high exposure levels that significantly raised the temperature of the brain (Foster and Pickard, 1987). The issue reappeared in the late 1980s, with the report that magnetic resonance imaging fields alter the blood-brain barrier in rats (Shivers, 1987). Other groups (including the group that initially reported the effect) could not confirm this finding (Prato et al., 1992; Liburdy et al., 1992). The wheel turns: just this year a Swedish group (Salford, 1994) reported that microwaves can affect the blood-brain barrier of rats. To

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review carefully this literature, one would have to weigh all of the conflicting reports on this subject. It is not clear what if anything of significance is there, apart from the obvious effects of excessive heating.

Carpenter, in the final chapter, concludes "it is too early to accurately evaluate the public health significance of electromagnetic fields on human health." In what sense is it too early? This is hardly virgin scientific territory. One digest lists 15,500 scientific and engineering papers published since 1972 related to biological effects, mechanisms of interaction, and clinical applications of electric and magnetic fields (Information Ventures, 1994). Nearly 100 epidemiology studies, and since 1990 more than a dozen long-term animal studies, have appeared, related to the question of electromagnetic fields and cancer. It is not too early to sift through the scientific evidence, and to weigh carefully the evidence for hazards, paying close attention to the validity and relevance of individual studies. A dozen or more consensus groups have done this, of course, finding consistently that the evidence for a real hazard from weak electromagnetic fields is weak and unconvincing. A British committee chaired by the eminent epidemiologist Sir Richard Doll, for example, found "no firm evidence" of a link between exposure to electromagnetic fields and cancer (National Radiological Protection Board, 1992). It is not too early to compare the risks, if any exist, with other risks we all face in daily life, or to place the issue in the context of other public health problems in our society.

But in a sense Carpenter is right. New issues are emerging, faster than older issues can be resolved. In the 1960s and 70s, a hot topic was the possible health effects of low-level microwave energy. (Remember the flap over the microwave-irradiation of the U.S. Embassy in Moscow?) Concerns about possible health risks of strong 60 Hz *electric* fields figured prominently in a lawsuit in the 1970s against a proposed high voltage power line in New York; its settlement funded the New York Power Lines Project that was supposed to address the health concerns once and for all. More recently (in part because of an epidemiology study funded by the Power Lines Project), public attention has shifted to possible health effects of the weak *magnetic* fields from neighborhood distribution lines. Other recent issues include speculated hazards from cellular telephones, police radar units, and video display terminals. The latest concern (from abstracts of two forthcoming scientific papers being circulated on the Internet) is a possible link between having an "electrical" occupation and Alzheimer's disease. Despite decades of research, public controversy, and litigation (Foster, 1993), few if any measurable health benefits have resulted from these controversies. If there is a problem, how can we identify it most efficiently? If science cannot identify a problem clearly or show that none exists, how can we develop the collective wisdom to live with the uncertainty?

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Statistical Thermodynamics of Chemists and Biochemists by Arieh Ben-Naim

Plenum Press, New York, 1992. 697 pages. $85.00

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This is the latest in a series of monographs by the author on the statistical thermodynamics of systems of biological interest. The other books include Water and Aqueous Solutions (1974), Hydrophobic Interactions (1980), and Solvation Thermodynamics (1987). The new book appears to contain much of the material in these earlier monographs.

The book consists of eight chapters. The first three give the general theory and many of the concepts that are used in the later part of the book. The basic relations of statistical thermodynamics are summarized in the rather short first chapter. The concept of the "frozen equilibrium" is introduced early and is used extensively throughout the entire book. The remainder of the general theory part is devoted